CERTAIN RELATIONS BETWEEN ROOT DEVELOPMENT AND TILLERING IN WHEAT: SIGNIFICANCE IN THE PRODUCTION OF HIGH-PROTEIN WHEAT

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In two other papers,[1] the writer has shown how differences in the protein content and in the consequent quality of a "soft white" spring wheat (White Australian) are causally related to the nitrogen nutrition of the wheat plant. The conditions that made for the production of high-protein wheat in the investigation cited arose from applications of nitrogen at much later growth phases of the plant than that indicated by the seeding or early seedling stage. Abundant tillering and culm production were obtained from the cultures which received nitrogen late in the growing period, that is, from 48 to 110 days after planting. The cultures that received nitrogen at the time of planting tillered sparsely and produced fewer culms, usually only one per plant.

That such marked differences in tillering could be obtained from equivalent applications of nitrogen per culture, applied, however, at different growth periods of the plant, suggested further study as to the causal conditions for these results. The cultures that produced the high-protein wheat also produced a much larger amount of total dry matter, this being partly accounted for by the abundant tillering. Obviously, this fact would suggest that the high-protein wheat cultures absorbed and utilized more nitrogen than the plants which produced the low-protein wheat, and this in view of the facts that all the cultures received the same amounts of nitrogen and that those that had the application of nitrogen during the longest period of time absorbed less than did those that had it for a much shorter period.

That these differences in the amount of nitrogen absorbed by the plant may be accounted for by conditions arising out of differences in the extent of the root development of the cultures at the time nitrogen was supplied seemed to be a plausible explanation. It is generally known, and was also observed by the writer in the investigation cited, that the root development of wheat (and the same seems to hold for many other plants) is decidedly affected by the supply of nutrients in the soil in which the plants are rooted. The quantitative relation, however, of differences in the

[1] On the protein content of wheat. Science, n. ser. **52** : 446, 447. 1920. Certain relations between the protein content of wheat and the length of the growing period of the head-bearing stalks. Soil Sci. **13**: 135–138. 1922.

extent of the root development of a plant to the extent of its top, when grown under different sets of conditions, has not been sufficiently studied. Especially is this true in soil cultures, where it is difficult to make exact determinations. It is conceivable that the kind of root development a plant may have when a treatment such as an application of nitrogen is made to it may be a very important factor that affects materially the nature of the subsequent responses of the plant.

In order to obtain data as to what effect differences in the extent of root development of wheat seedlings would have upon the tillering of the plants when grown in the same nutrient solutions, the following experiment with water cultures was carried out: Wheat seedlings 8 to 10 centimeters high, having roots 10 to 12 centimeters long, were set up according to the usual method employed for solution-culture investigations, and were grown for 25 days in two-quart containers filled with tap water from the laboratory. At the end of this period, the seedlings had developed a very extensive root system. Roots from 50 to 70 centimeters long had formed while the tops had grown only a little, attaining a height of approximately 10 to 12 centimeters. Sets of these cultures with large root development were then transferred, respectively, to several different kinds of complete nutrient solutions. At the time these several sets were placed in the nutrient solutions, other sets of wheat seedlings a few days old having shoots 8 to 10 centimeters high and a comparatively small root development, *viz.*, roots about 10 to 12 centimeters long (similar to those used for the tap-water series), were set up to serve as controls, being placed in similar nutrient solutions to those in which were placed the sets of large root development. The investigation, therefore, as planned, concerned itself with a study of some of the effects the same kind of nutrient solution would have upon wheat seedlings of different root development, some having a large root development and others a comparatively small root development at the time the cultures were placed in the nutrient solutions. In one class of cultures, practically one half of the total dry weight was contained in the roots, while in the other class about one fourth of the total dry matter was roots. The roots of the cultures grown in tap water for 25 days were from four to five times as long as their tops. The lengths of the roots of the plants not so treated were only a little greater than those of their tops. The weight of the tops of the two sets of cultures was about the same, but the weight of the roots in the one was about four times the weight of the other. Subsequent treatment of these two classes of cultures was the same throughout the test period employed. The data in table 1 are given as an example of the results obtained:

TABLE I. *Effect of Differences in Extent of Root Development of Wheat Seedlings upon Tillering*

Average of 10 cultures (5 seedlings per culture) grown 4 weeks in nutrient solution

	Length of Tops (cm.)	Length of Roots (cm.)	Weight of Tops (g.)	Weight of Roots (g.)	No. of Tillers per Plant
Cultures grown in tap water 25 days after seedlings were set in corks......	11	62	0.19	0.18	5.4
Cultures transferred directly to nutrient solutions at time seedlings were set in corks........................	10	12	0.17	0.045	1.2

It will be noted from the table that the cultures of large root development tillered much more profusely than did those cultures which did not have large root development at the time they were placed in the nutrient solution. The question may now be asked as to the cause of the profuse tillering in the one case and of its lack in the other. The answer seems to be that in one case the cultures absorbed a greater amount of nutrients from the solution than they did in the other case. The cultures of large root development absorbed a much larger amount of nutrient from the solution because they had a larger root area with which nutrients came in contact. The profuse tillering of these cultures with the large root development, therefore, may presumably be accounted for by the fact that the cultures took up more nutrient than was needed by the plants for the normal development of the individual shoots of the seedlings. The consequence was a great vegetative response in the form of tillers which arose from the root crown. The cultures with the small but normal root development, while they produced some tillers, nevertheless did not produce them in any way comparable in number to those produced by the cultures with large root development. Presumably because of the smaller root development in these cultures, an excess of nutrients was not absorbed by these seedlings, and the condition that made for the profuse tillering above stated did not prevail. Although the cultures of large root development tillered much more profusely in all the different nutrient solutions used than did those of relatively small root development, nevertheless the chemical properties of the nutrient solution itself, as indicated by different concentrations of certain salts used, were also an important factor that affected tillering. This was shown by the fact that cultures of similar root development differed in the number of tillers produced, depending upon the kind of nutrient solution in which the seedlings were placed.

It seems that data obtained with these solution cultures show why good tillering was obtained with the soil cultures referred to in the papers cited. As stated, the soil used in that experiment was low in nitrogen, so that the conditions of the growing medium in respect to the paucity

of this element (nitrogen) may be compared to that existing in tap water. The wheat seedlings grown in the nitrogen-poor soil developed a large root system after a period of several weeks. When nitrogen was added to these cultures, relatively large amounts of this nutrient were absorbed by the plant. This was more than was needed for the normal growth of the single shoots these seedlings had. The result from this treatment was a renewal and stimulation of vegetative growth. This gave rise to abundant tillering, which followed soon after the application of nitrogen. The cultures that received nitrogen at the time of planting obviously did not grow in a nitrogen-poor soil and consequently did not develop the same kind of root system as did those cultures grown in a nitrogen-poor soil.

That the large root development in proportion to that of tops obtained in the cultures grown in tap water was primarily due to the deficiency of nitrogen, was further substantiated by the fact that this peculiar large root development was obtained with wheat seedlings grown in several different kinds of nitrogen-free "nutrient solutions" prepared from different kinds of salts. This, however, does not mean that a nitrogen-poor medium is the only condition that may make for an abnormally large root development in wheat seedlings or in other plants.

It seems that the results obtained from these simple tests show that the extent of the root development of the wheat seedlings when nutrients are made available or become so is a matter of importance in the economy and culture of this important food plant.

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